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# Observations on the length and diameter of vessels forming the circle of Willis

SYLVIA KAMATH

*Department of Anatomy, St John's Medical College, Bangalore – 560 034, South India*

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## INTRODUCTION

Though many workers have reported abnormalities in the diameter of the vessels forming the circle of Willis, the normal dimensions of these vessels have hitherto remained unreported. Vessels have been described as 'abnormally narrow', 'thread-like', or 'string-like' but actual diameters have rarely been measured, neither has it been stated what diameter could be considered abnormal. Two reports appear in the literature, that of Alpers, Berry & Paddison (1959), and that of Fetterman & Moran (1941) stating that an external diameter of 1 mm, and 0·5 mm, or less, respectively, would be considered abnormal. They also reported 27·4 % and 23 % abnormality, respectively. A higher percentage of abnormality has been reported in the mentally ill and in patients with cerebrovascular catastrophy, indicating a possible linkage, the one being consequent on the other. A knowledge of the normal size of these vessels may also be of use to the surgeon in assessing the feasibility of shunt operations and in the choice of patients. This study presents the average length and diameter of vessels forming the circle of Willis, in the brains of 100 cadavers, in an attempt to establish a norm.

## MATERIALS AND METHODS

The length and external diameter of vessels were measured where they formed part of the circle of Willis, i.e. the internal carotid between its posterior communicating and anterior cerebral branches, the anterior and posterior cerebrals from their points of origin to the point where they were joined by a communicating artery, and the communicating arteries in their entirety. The specimens were obtained from 100 embalmed dissecting room cadavers collected from different regions of South India. A caliper graduated to measure up to 0·1 mm was used. Arteries of less than 1 mm diameter were considered abnormal, barring the communicating arteries, where less than 0·5 mm diameter was considered abnormal.

## RESULTS

Table 1 shows the average lengths and diameters of the vessels forming the circle of Willis. Table 2 gives the greatest and smallest values obtained and the coefficient of variation for the dimensions of each component of the circle. The anterior communicating artery showed the greatest variation in length and the posterior communicating artery the greatest variation in diameter.

Table 1. *Average length and external diameter of arteries forming the circle of Willis*

| Name of artery | Length (cm) | | Diameter (cm) | |
|---|---|---|---|---|
| | Right | Left | Right | Left |
| 1. Posterior cerebral artery | 0·68±0·27 | 0·69±0·31 | 0·21±0·07 | 0·22±0·06 |
| 2. Posterior communicating artery | 1·35±0·34 | 1·33±0·33 | 0·15±0·07 | 0·14±0·07 |
| 3. Internal carotid artery | 0·48±0·15 | 0·47±0·15 | 0·42±0·09 | 0·42±0·09 |
| 4. Anterior cerebral artery | 1·47±0·30 | 1·38±0·27 | 0·22±0·06 | 0·24±0·05 |
| 5. Anterior communicating artery | (0·25±0·18) | | (0·19±0·09) | |

Table 2. *Greatest and smallest measured and Coefficient of Variation (CoV) of dimensions of the arteries forming the circle of Willis*

| Name of artery | Length (cm) | | | Diameter (cm) | | |
|---|---|---|---|---|---|---|
| | Greatest | Smallest | CoV | Greatest | Smallest | CoV |
| 1. Right posterior cerebral artery | 1·53 | 0·20 | 39·71 | 0·49 | 0·06 | 35·24 |
| 2. Left posterior cerebral artery | 1·93 | 0·21 | 44·59 | 0·50 | 0·05 | 28·38 |
| 3. Right posterior communicating artery | 2·32 | 0·39 | 25·19 | 0·33 | 0·04 | 47·33 |
| 4. Left posterior communicating artery | 2·46 | 0·62 | 24·96 | 0·35 | 0·04 | 48·17 |
| 5. Right internal carotid artery | 1·15 | 0·04 | 30·64 | 0·66 | 0·24 | 22·46 |
| 6. Left internal carotid artery | 0·98 | 0·16 | 30·85 | 0·74 | 0·27 | 21·69 |
| 7. Right anterior cerebral artery | 2·56 | 0·34 | 20·26 | 0·39 | 0·06 | 26·82 |
| 8. Left anterior cerebral artery | 2·10 | 0·31 | 19·84 | 0·36 | 0·11 | 22·14 |
| 9. Anterior communicating artery | 1·04 | 0·05 | 73·49 | 0·49 | 0·04 | 44·79 |

Table 3. *Numbers of arteries with abnormal diameter observed in* 100 *circles*

| Name of artery | Total | Number on right | Number on left |
|---|---|---|---|
| 1. Posterior cerebral artery | 11 | 8 | 3 |
| 2. Posterior communicating artery | 10 | 3 | 7 |
| 3. Internal carotid artery | Nil | Nil | Nil |
| 4. Anterior cerebral artery | 2 | 2 | Nil |
| 5. Anterior communicating artery | 2 | — | — |
| Total | 25 | 13 | 10 |

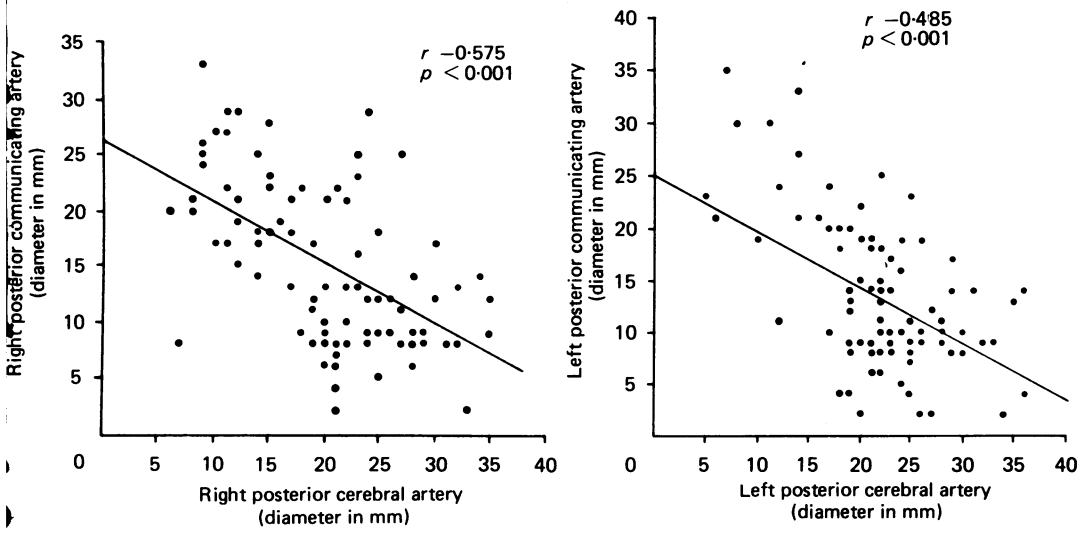


Fig. 1. (A) Scattergram of the diameters of the right posterior cerebral and right posterior communicating arteries. (B) Scattergram of the diameters of the left posterior cerebral and left posterior communicating arteries.

The occurrence of arteries with abnormal diameter is given in Table 3. Abnormal diameter occurred most frequently in the posterior cerebral arteries, usually on the right side, of which 8 examples were found. The left posterior communicating was of abnormal diameter in 7 specimens.

An inverse relationship was observed between the diameters of the posterior cerebral and posterior communicating arteries of the same side. The results were subjected to statistical analysis and found to be highly significant. Right side $r = -0{\cdot}57$, $P < 0{\cdot}001$. Left side $r = -0{\cdot}48$, $P < 0{\cdot}001$. (See Fig. 1 A and B.)

## DISCUSSION

The length and diameter of arteries forming the circle of Willis was found to be variable. Abnormally small diameter was observed in 25 arteries of 24 circles in this series. Alpers *et al.* (1959), Fetterman & Moran (1941), Riggs & Rupp (1963), Alpers & Berry (1963) and Raja Reddy, Prabhakar & Dayananda Rao (1972) have reported hypoplasia of vessels as the commonest anomaly in the circle of Willis. Anomalous form was a commoner observation in this series. Whereas these workers have reported abnormal diameters most commonly in the posterior communicating arteries, followed by the posterior cerebrals, others (Windle, 1887; Fawcett, 1905) observed them more commonly in the posterior cerebrals than in the posterior communicating. The present findings concur with the latter, although the incidence of abnormality is much higher in the present series.

The volume of blood flow through a vessel is inversely related to the length of the vessel and directly related to its diameter, i.e. fourth power to its radius (Keele & Neil, 1971). Therefore, blood flow through shorter and wider vessels is more efficient. From this study it appears that the composite vessels of the circle, have, in a majority of cases, a greater length, and a smaller diameter in the right half of the circle. Hence, blood flow will be better in the left half, and thus the left hemisphere has on

the whole a better blood supply. This is in keeping with the dominance of the left hemisphere and the commoner occurrence of right handedness (Warwick & Williams, 1973). Orlandini (1970) has reported similar observations, i.e. the circumference of the vertebral and internal carotid arteries in his series was greater on the left side. However, earlier observations suggested that the blood supply to the left half of the brain was, on the whole, less complete than that to the right side (Windle, 1887; Mitterwallner, 1955).

The circle of Willis is not an equalizer and distributor of blood from different sources, there being no mingling of blood from different sources, in the circle, under normal circumstances. It functions as an anastomosis and offers a potential shunt under abnormal conditions such as might occur during an occlusion or spasm (Rogers, 1946). Hence, an idea of the normal dimensions of these vessels may contribute greatly to a surgeon's assessment of the feasibility of 'shunt operations'.

Abnormal narrowing of vessels was a commoner occurrence on the right side than on the left in this series. This may be related in some way to the need for a better blood supply to the left hemisphere. The only artery which showed a smaller average diameter on the left side, coupled with a higher incidence of abnormal diameters on the left side, was the posterior communicating artery. Since a significant inverse relationship existed between the diameters of the posterior communicating and posterior cerebral arteries of the same side, a smaller posterior communicating on the left would be associated with a larger posterior cerebral on that side, thus ensuring better blood supply to the left hemisphere from two sources, viz. basilar via posterior cerebral and internal carotid via anterior and middle cerebrals.

The internal carotid arteries and the left anterior cerebral artery did not exhibit abnormal form throughout this series.

## SUMMARY

The dimensions of vessels forming the circle of Willis were studied in 100 fixed brains from cadavers. The coefficient of variation for length was greatest for the anterior communicating artery, and that for diameter was greatest for the posterior communicating artery.

Abnormally narrow diameter occurred in 25 vessels of 24 circles and was most frequently seen in the posterior cerebral (11) and posterior communicating arteries (10). A significant inverse relationship existed between the diameters of the posterior cerebral and posterior communicating arteries of the same side. The left cerebral hemisphere appeared to enjoy a better blood supply.

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## REFERENCES

ALPERS, B. J. & BERRY, R. G. (1963). The circle of Willis in cerebral vascular disorders. *Archives of Neurology* **3**, 398–402.

ALPERS, B. J., BERRY, R. G. & PADDISON, R. M. (1959). Anatomical studies of the circle of Willis in normal brain. *Archives of Neurology and Psychology (Chicago)* **81**, 409–418.

FAWCETT, E. (1905). The circle of Willis: An examination of 700 specimens. *Journal of Anatomy and Physiology* **40**, 63–69.

FETTERMAN, G. H. & MORAN, J. J. (1941). Anomalies of the circle of Willis in relation to cerebral softening. *Archives of Pathology* **32**, 251–257.

KEELE, CYRIL A. & NEIL, ERIC (1971). *Samson Wright's Applied Physiology*, 12th ed., p. 72. Oxford University Press.

MITTERWALLNER, F. VON (1955). Variationen statistische Untersuchungen an den Baselen Hirngefassen. *Acta anatomica* **24**, 51–87.

ORLANDINI, G. E. (1970). The ratified circumference of the principal arteries of the base of the brain. *Archivio italiano di anatomia e di embriologia* **75**, 49–79.

RAJA REDDY, D., PRABHAKAR, V. & DAYANANDA RAO, B. (1972). Anatomical study of circle of Willis. *Journal of the Neurological Society of India* **20**, 8–12.

RIGGS, H. E. & RUPP, C. (1963). Variation in the form of the circle of Willis. *Archives of Neurology* **3**, 8–14.

ROGERS, LAMBERT (1946). The function of the circulus arteriosus of Willis. *Brain* **70**, 171–178.

WARWICK, R. & WILLIAMS, P. L. (ed.) (1973). *Gray's Anatomy*, 35th ed., p. 957.

WINDLE, B. C. (1887). On the arteries forming the circle of Willis. *Journal of Anatomy and Physiology* **22**, 289–293.